91602
new 82-10

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

ontario hydro
research division

COMPLIMENTARY COPY
Please Credit: Ontario Hydro Research if Reproduced in Whole or in Part

THE USE OF SHORT TERM, CONTROLLED ENVIRONMENT EXPERIMENTS FOR THE SELECTION OF COVER CROPS WITH HIGH INTERFERENCE POTENTIALS. I. IDENTIFICATION OF SOME PARAMETERS IMPORTANT TO THE EXPERIMENT.

Report No 90-99-K

D. Brown
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

A protocol is being developed for a short term, controlled environment experiment to be used to rank several cover crop candidates by their inhibitory effects on tree growth. This is a preliminary study which investigates the importance of crop age, tree age, tree species, fertilization rate and watering rate on the outcome of a crop vs. tree interference experiment.

job	file	date	report no.
34-572-031	834.1	May 22, 1990	90-99-K

91602
new 82-10

91-00814/

ontario hydro
research division

EXECUTIVE SUMMARY

THE USE OF SHORT TERM, CONTROLLED ENVIRONMENT EXPERIMENTS FOR THE SELECTION OF COVER CROPS WITH HIGH INTERFERENCE POTENTIALS. I. IDENTIFICATION OF SOME PARAMETERS IMPORTANT TO THE EXPERIMENT.

D. Brown

There has been an increased awareness within Ontario Hydro of the need to develop an integrated vegetation management program which reduces the use of herbicides. Such a plan requires a strategy involving the delicate blending of the vegetation's inherent ability to interfere with tree invasion, with mechanical and manual tree removal methods and the effective use of herbicides. The long term success of this integrated policy, in terms of cost effectiveness and environmental acceptability, will be dependent upon the stability of the vegetation.

Most open vegetation ecosystems do not have the ability to resist tree invasion. In these situations, it may be advisable to replace this vegetation with a groundcover that has a proven ability to inhibit the establishment and growth of tree species. Although a literature review indicated that a cover crop approach can be effective at reducing tree growth, there was insufficient evidence available to recommend any species for immediate use by Ontario Hydro. Further research is required to identify plant species which have a demonstrated ability to control undesirable vegetation in rights-of-way situations. This will require a method of rating numerous species on their interference abilities. The preliminary development of such a laboratory based screening method is the objective of this study.

The experiment consists of comparing the size of a target tree grown in the presence and absence of a cover crop. The target trees consisted of either 2 yr old sugar maple (*Acer saccharum*) transplants, Carolina poplar (*Populus x canadensis*) cuttings, 2 yr old white spruce (*Picea glauca*) transplants or white spruce seeds. The groundcovers tested consisted of 7 grasses (tall fescue (*Festuca arundinacea*), champ timothy (*Phleum pratense*), climax timothy (*P. pratense*), red top (*Agrostis gigantea*), creeping red fescue (*F. rubra*), Kentucky blue grass (*Poa pratense*), juno orchard grass (*Dactylis glomerata*)), 5 legumes (white clover (*Trifolium repens*), crown vetch (*Coronilla varia*), birdsfoot trefoil (*Lotus corniculatus*), white sweet clover (*Melilotus alba*), yellow sweet clover (*M. officinalis*)) and an unseeded bare ground control.

The outcome of the experiments was dependent upon the conditions under which they were conducted. The parameters tested in this study consisted of tree species, tree age, groundcover species, groundcover age, fertilization rate, and watering rate. A well established groundcover (1 month old) has a higher interference ability towards white spruce seeds. An established legume

job	file	date	report no.
34-572-031	834.1	May 22, 1990	90-99-K

groundcover was more inhibitory than an established grass cover. When the crops were seeded at the same time as the spruce, the spruce seeds exhibited higher survival and greater growth. In this situation, the faster establishing grasses inhibited spruce seed germination more, whereas the legumes inhibited long term (4 month) growth and survival of the spruce. When poplar cuttings were used as the target tree, the grasses were the better inhibitors over the long term.

Very few of the 2 year old white spruce transplanted into an established groundcover survived to the end of the experiment. In contrast, all the sugar maple transplants survived. The rate of fertilization or watering did not affect the interference potential of the white clover or climax timothy used in this experiment. White clover was the better inhibitor of the white spruce, while the timothy tended to inhibit the sugar maple more. The growth of sugar maple was inhibited by the higher watering rate, while the 2 fertilization rates did not affect its growth. The lack of a fertilization effect was surprising. Both levels used may have been in excess of that required for growth.

Biomass was a significant component of the interference ability of the various groundcovers. In the experiment using poplar cuttings, the total above ground biomass of the cover crop could explain 37.5% of the variation in poplar height. When groundcover biomass was used as a covariate in the statistical analysis, no additional variation in poplar growth could be attributed to the different cover crops.

The overall results of this study suggest that the interference potential of the 5 legumes tested are relatively comparable, and that the 7 grasses also have a similar interference potential. Although the differences in biomass can explain this result, it is also reminiscent of a guild concept. A guild is a grouping of plants, defined by their morphology and life history traits, which have a similar ecological role. Additional studies are required to determine if the application of a guild concept is beneficial for the selection of cover crops.

This series of studies has indicated that the outcome of an interference comparison is affected by cover crop age and tree species. Additional experiments using more realistic fertilization rates will be required to determine if fertilization is an important parameter. Studies are also needed to address the potential effects of different soil types on the outcome of the interference comparisons. Once the importance of these parameters has been determined, a protocol can be finalized which will allow for the ranking of the interference potential of various cover crop species in a short term (3 months), controlled experiment.

TABLE OF CONTENTS

		Page
1.0	**INTRODUCTION**	1
2.0	**GENERAL GROWTH CONDITIONS**	2
3.0	**EXPERIMENT 1. SPRUCE SEED STUDY**	2
3.1	Methods	2
3.2	Results	2
4.0	**EXPERIMENT 2. POPLAR CUTTINGS**	6
4.1	Methods	6
4.2	Results	6
5.0	**EXPERIMENT 3. SPRUCE AND MAPLE TRANSPLANTS**	9
5.1	Methods	9
5.2	Results	10
6.0	**DISCUSSION**	14
7.0	**CONCLUSIONS**	16
REFERENCES		18
DISTRIBUTION		last page

LIST OF FIGURES

		Page
Figure 1	The effect of 13 groundcovers on the germination, survival and growth of white spruce seeds.	5
Figure 2	The effect of 13 groundcovers on the growth of poplar cuttings.	7
Figure 3	The relationship between poplar height and groundcover biomass.	8
Figure 4	The effect of 2 fertilization and watering rates on the growth of white spruce transplants.	11
Figure 5	The effect of groundcover, fertilizer and watering on the growth of sugar maple transplants.	13

LIST OF TABLES

Table 1	Seeding rates for the grasses and legumes used in the experiments.	3
Table 2	The results of the two-way ANOVA showing the effects of 13 established and concurrently seeded groundcovers on the germination of 25 white spruce seeds, and on the survival and growth of the 4 largest germinants.	4
Table 3	The results of the ANOVA showing the effects of 13 concurrently seeded groundcovers on the mean height, root biomass, shoot biomass, chlorophyll content and root: shoot ratio of the surviving poplar sprouts on day 155.	9
Table 4	The results of the ANOVA showing the effects of a factorial combination of 2 fertilization and 2 watering rates on the height increment, root collar diameter, root biomass, shoot biomass, needle biomass, and root:shoot ratio of white spruce transplants growing in the bare ground control.	10
Table 5	The results of the ANOVA showing the effects of a factorial combination of 3 groundcovers, 2 fertilization and 2 watering rates on the height increment, root collar diameter, root biomass, shoot biomass, foliage biomass and root: shoot ratio of the sugar maple transplants.	12

91601
new 82-10

ontario hydro
research division

To: Dr. D. Mills
Director of Research

THE USE OF SHORT TERM, CONTROLLED ENVIRONMENT EXPERIMENTS FOR THE SELECTION OF COVER CROPS WITH HIGH INTERFERENCE POTENTIALS. I. IDENTIFICATION OF SOME PARAMETERS IMPORTANT TO THE EXPERIMENT.

1.0 INTRODUCTION

Ontario Hydro has an extensive network of transmission and distribution rights-of-way. A considerable effort is required to maintain these lands with a type of vegetation compatible to the needs of the electrical system. The Corporation has an obligation to manage this area in a way which is cost effective, has minimal environmental impact and is acceptable to both the landowners and the general public. In the past, selective herbicide applications were used to remove incompatible trees. Recently, the Corporation has responded to increased concern of the potential negative environmental impact of herbicides by increasing the restrictions on the amount of herbicide usage and its methods of application.

These restrictions have placed a larger emphasis on manual, mechanical and biological options for vegetation control. The replacement of the natural right-of-way vegetation with a cover crop that has a proven ability to resist tree invasion and/or growth is one of many alternative control methods which warrant consideration. A literature review uncovered some studies where cover crops were able to inhibit tree growth, but concluded that there was insufficient evidence to make specific recommendations to Ontario Hydro (Brown 1989a). The review suggested that additional research is necessary for the selection of appropriate crop species and for the verification of the viability of the cover crop approach in field situations.

The Ontario Hydro Research Division is developing an integrated cover crop research program based on the recommendations of the literature review. A small field study comparing 4 cover crops and the natural right-of-way vegetation has been initiated near Tobermory (Brown 1990). A search is underway on rights-of-way in the vicinity of Essa TS to identify naturally occurring plant communities which exhibit a high resistance to tree growth (Brown 1989b). The preliminary development of a laboratory based screening method for cover crop selection is the object of this report.

The selection of an appropriate cover crop must be based on three main criteria. The crop should inhibit the invasion and growth of incompatible trees. The crop must form a stable, long lived groundcover. Finally, the species must be able to grow on the specified right-of-way with sufficient vigour to ensure criteria 1 and 2 are met. Several other criteria will be involved in

defining the appropriateness of a crop species (Suffling 1979), however these 3 criteria represent the minimum that must be met to ensure success for that species.

To meet the first criterion, an experimental protocol must be developed which allows for the rapid determination of a plant's interference potential with respect to a tree species. Such a procedure will be used to scan various crop species, thus it is best done under repeatable, controlled conditions in a phytotron, greenhouse or growth room facility. The procedure will involve growing the test species and a target tree in the same container, and comparing the growth of the target to a tree grown in a bare ground control.

Several factors may affect the outcome of a crop vs tree interference experiment. Crop size, age and density, tree size, age and density, resource supply rate, soil type, container size, growth temperature and light intensities can be manipulated in a controlled experiment. Other factors, such as climate, grazing, disturbance, environmental heterogeneity and scale cannot be realistically duplicated in a laboratory setting. The purpose of this report is to determine the effect of some of the controllable factors (tree species and age, crop age, nutrient supply rate and water supply rate) on the outcome of the interference experiments.

2.0 GENERAL GROWTH CONDITIONS

All experiments were conducted in a controlled-environment growth room. Temperature was set at 25°C day, 20°C night, with a 15 h photoperiod. High pressure sodium lamps were used as the sole lighting source. Light intensities at the bench top ranged from 70 to 120 umole photons $m^{-2}s^{-1}$. All plants were grown in 15 cm pots using artificial soil mixtures (Promix C, Plant Products).

3.0 EXPERIMENT 1. SPRUCE SEED STUDY

This study was undertaken to determine the interference effects of newly seeded and well established groundcovers on the germination, survival and growth of white spruce (*Picea glauca*) seeds.

3.1 Methods

The groundcovers consisted of 7 grasses (tall fescue (*Festuca arundinacea*), champ timothy (*Phleum pratense*), climax timothy (*P. pratense*), red top (*Agrostis gigantea*), creeping red fescue (*F. rubra*), Kentucky blue grass (*Poa pratense*), and juno orchard grass (*Dactylis glomerata*)), 5 legumes (white clover (*Trifolium repens*), crown vetch (*Coronilla varia*), birdsfoot trefoil (*Lotus corniculatus*), white sweet clover (*Melilotus alba*), and yellow sweet clover (*M. officinalis*)) and an unseeded bare ground control.

To mimic the interference effects of an established crop and a newly seeded crop on the tree, the crops were seeded (at a density of 1 seed cm^{-2} (Table 1)) on 2 dates. The established groundcover was sown 36 days before addition of the spruce seeds, while the new crops were sown concurrently with the spruce. The experiment was arranged as a complete random design with 5 replicates for each of the 26 treatments. The plants were watered to excess 3 times weekly, and fertilized weekly at a rate of 0.125 g pot^{-1} of 20:20:20 NPK fertilizer.

Table 1

Seeding rates for the grasses and legumes used in the experiments.

Species (code)	Seed Rate[1] (g 15 cm pot^{-1})
Grasses	
tall fescue (TF)	0.375
champ timothy (CHT)	0.054
climax timothy (CLT)	0.067
red top (RT)	0.018
red fescue (RF)	0.139
Kentucky blue grass (KBG)	0.037
orchard grass (OG)	0.195
Legumes	
white clover (WC)	0.105
birdsfoot trefoil (BT)	0.260
crown vetch (CV)	0.615
white sweet clover (WSC)	0.390
yellow sweet clover (YSC)	0.425

[1] seed weights were obtained from Ontario Hydro (1983). This weight corresponds to a seed density of 1 seed cm^{-2}

The white spruce seeds (MNR seed source number 012-52-000-00, lot 680119) were stratified by soaking the seeds at 4°C for 24 h, followed by storage at 4°C for 30 days. The seeds were then sown into the cover crops at a density of 25 seeds pot^{-1}. Seed germination was estimated as the number of seedlings surviving on day 25. The spruce seedlings were then thinned to 4 pot^{-1}. The spruce were harvested after 113 days. Survival and growth were reported as the number and the mean dry weight (24 h at 80°C), respectively, of the surviving seedlings in each pot. These parameters were analyzed as a two factor ANOVA (analysis of variance) between the 13 groundcovers and 2 groundcover sowing dates. When the ANOVA indicated a significant groundcover effect, an LSD multiple range test was used to indicate differences between the cover crops.

3.2 Results

Table 2 describes the results of the ANOVA on the germination of the spruce seeds. Germination was significantly affected by the groundcover treatments ($p = 0.0019$). The sowing date of the cover crop did not have an overall effect, however an interaction between the groundcover treatment and the sowing date was observed ($p = 0.0341$). For the established groundcovers, the legumes tended to interfere more with spruce seed germination than the grasses (Figure 1a). White clover, crown vetch, red fescue, orchard grass and yellow sweet clover had the largest inhibitory effects. The highest germination rate was observed in the bare ground control. Spruce germination in the tall fescue, Kentucky blue grass, white sweet clover and climax timothy treatments did not differ from the control. In contrast, the grasses tended to have a higher inhibitory effect on spruce seed germination in the concurrently seeded groundcovers (Figure 1a). Orchard grass, white sweet clover, red fescue and champ timothy exhibited the most inhibitory effects. The other cover crops did not differ significantly from the control.

The groundcover seeding date has a highly significant effect on the survival of the 4 largest spruce germinants (Figure 1b). Very few spruce survived in the established groundcovers. Yellow sweet clover, red top and Kentucky blue grass were the only crops in which a spruce germinant survived until the end of the experiment. When the groundcover was seeded concurrently, all of the treatments had at least one replicate with a surviving spruce seedling. The groundcover treatment effect was significant for the concurrently seeded crops ($p = 0.004$, Table 2). The legumes had the largest inhibitory effects, whereas red fescue, red top, champ timothy, and Kentucky blue grass did not differ from the bare ground control. There was an even larger contrast between the cover crops and control in the mean dry weight of the surviving spruce seedlings (Figure 1c, Table 2). All the concurrently seeded crops inhibited growth more than the control. The red top and Kentucky blue grass groundcovers were the least inhibitory of the cover crops.

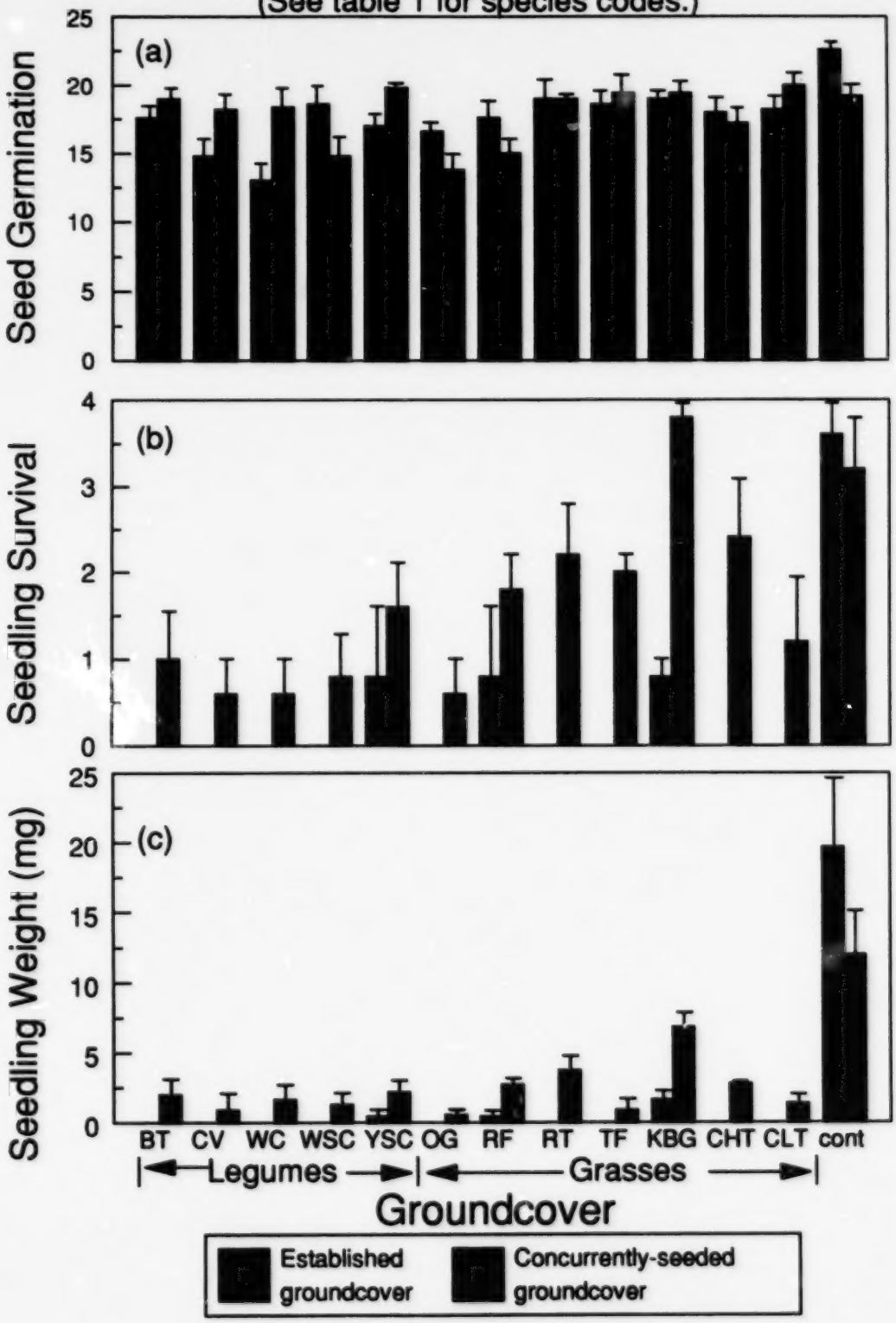
Table 2

The results of the two-way ANOVA showing the effects of 13 established and concurrently seeded groundcovers on the germination of 25 white spruce seeds, and on the survival and growth of the 4 largest germinants.

Growth Measure	Groundcover		Age		Cover x Age	
	F	*p*	F	*p*	F	*p*
germination	2.864	0.0019	0.380	0.5455	1.973	0.0341
survival	3.775	0.004				
dry Wt	7.839	0.000				

Figure 1: The effect of 13 groundcovers on the germination, survival and growth of white spruce seeds.

(See table 1 for species codes.)



4.0 EXPERIMENT 2. POPLAR CUTTINGS

This study was undertaken to determine the interference effects of the 13 different groundcovers on the growth of Carolina poplar (*Populus x canadensis*) cuttings.

4.1 Methods

The groundcovers consisted of the 7 grasses, 5 legumes and a bare ground control described earlier, seeded at a density of 1 seed cm^{-2} (Table 1) concurrently with the tree planting. A 14:14:14 NPK slow release fertilizer (4.46 g pot^{-1} of Nutricote 140, Plant Products) was added to the potting soil at the beginning of the experiment. (This fertilizer is designed to release 80% of it nutrients at a constant rate over a 140-day period at 25°C. Thus the fertilization rate is comparable to the 0.125 g pot^{-1} $week^{-1}$ used in the above experiment.)

Carolina poplar whips were obtained from the MNR nursery at St. Williams. The whips were cut into 15 cm stocks and planted onto the groundcovers, with 20 replicates for each treatment. One sprout was allowed to grow in each cutting. Any additional sprouts were pinched off as they appeared.

Height measurements were taken on days 50 and 87. The height, diameter, and the dry weight (24 h at 80°C) of the root and shoot of each sprout was taken at the final harvest. The chlorophyll content of the fifth leaf from the top was determined by grinding a 2.5cm leaf disc in 8 mL of 80% acetone and incubating at 4°C for 24 h in the dark. The resultant extract was centrifuged at 10,000 xg for 10 min and the absorbance was taken 663 nm. The chlorophyll content was expressed in absorbance units. The dry weight of the aboveground biomass of each groundcover was also measured at harvest time. Due to the large amount of work required, the final harvest was performed on days 112 to 168. Growth values were corrected to a uniform harvest date of 155 days using linear regression techniques.

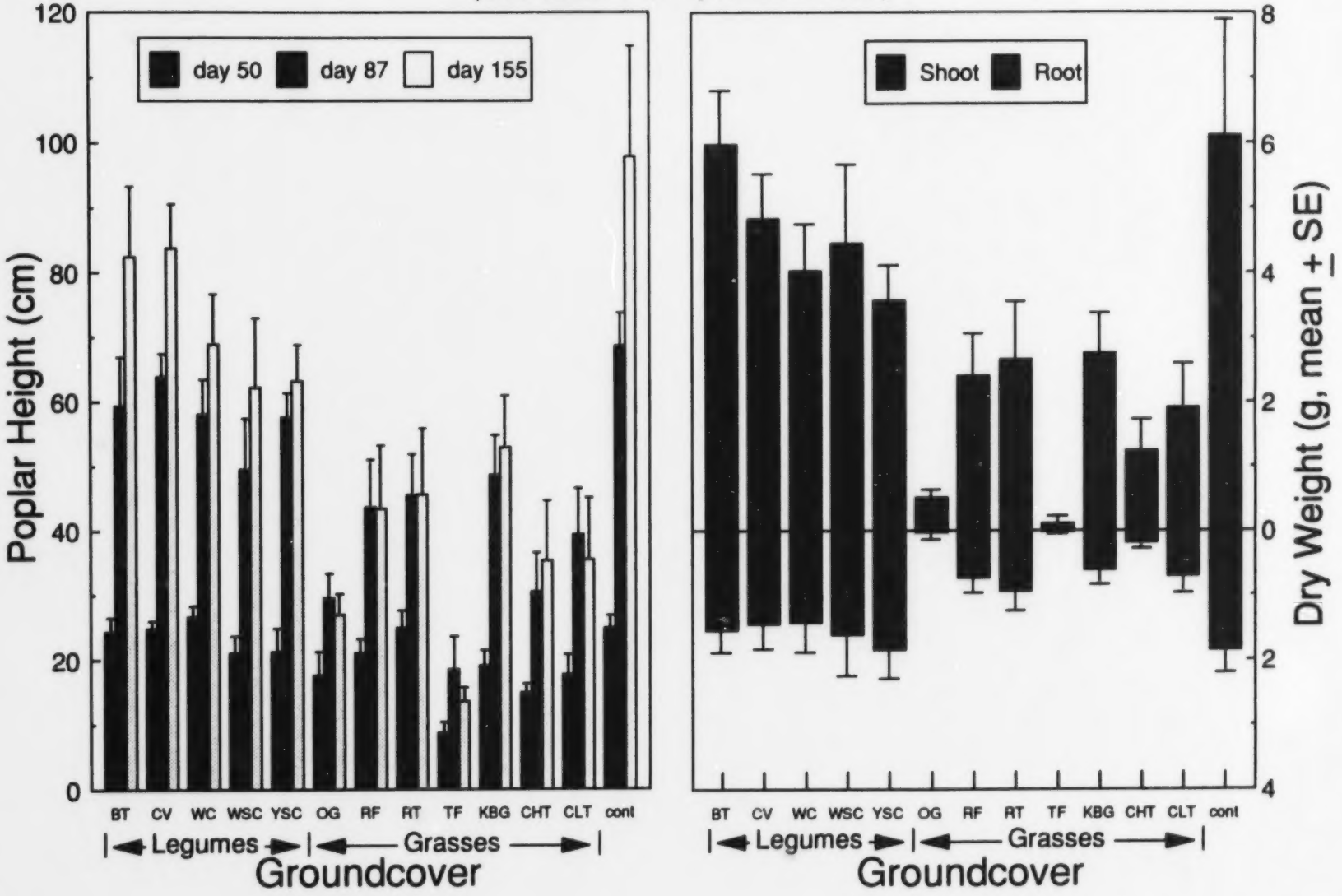
4.2 Results

Approximately 50% of the poplar cuttings did not sprout. Although the number of surviving cuttings ranged from 3 in orchard grass to 15 in the Kentucky blue grass groundcovers, there was no significant treatment effects (X^2 = 17.8, d.f. = 12, p = 0.1219).

The effect of the groundcovers on the height of the surviving poplar sprouts is shown in figure 2. The grasses have a larger inhibitory effect on poplar height than the legumes. These differences were evident by day 50 (tall fescue, climax timothy, champ timothy, orchard grass and Kentucky blue grass all inhibited growth more than the control), and became progressively larger as the experiment progressed. By day 87, red fescue, red top and white sweet clover also inhibited growth more that the control. The sprout height did not increase between days 87 and 155 in the grass groundcovers, whereas an increase in height was observed in all the legume covers at each sampling date. At the end of the experiment, the height did not differ significantly between any of the legumes and the bare ground control. The groundcover effects on sprout biomass paralleled the height results (Figure 2). Very little sprout biomass was accumulated in the orchard grass and tall fescue groundcovers.

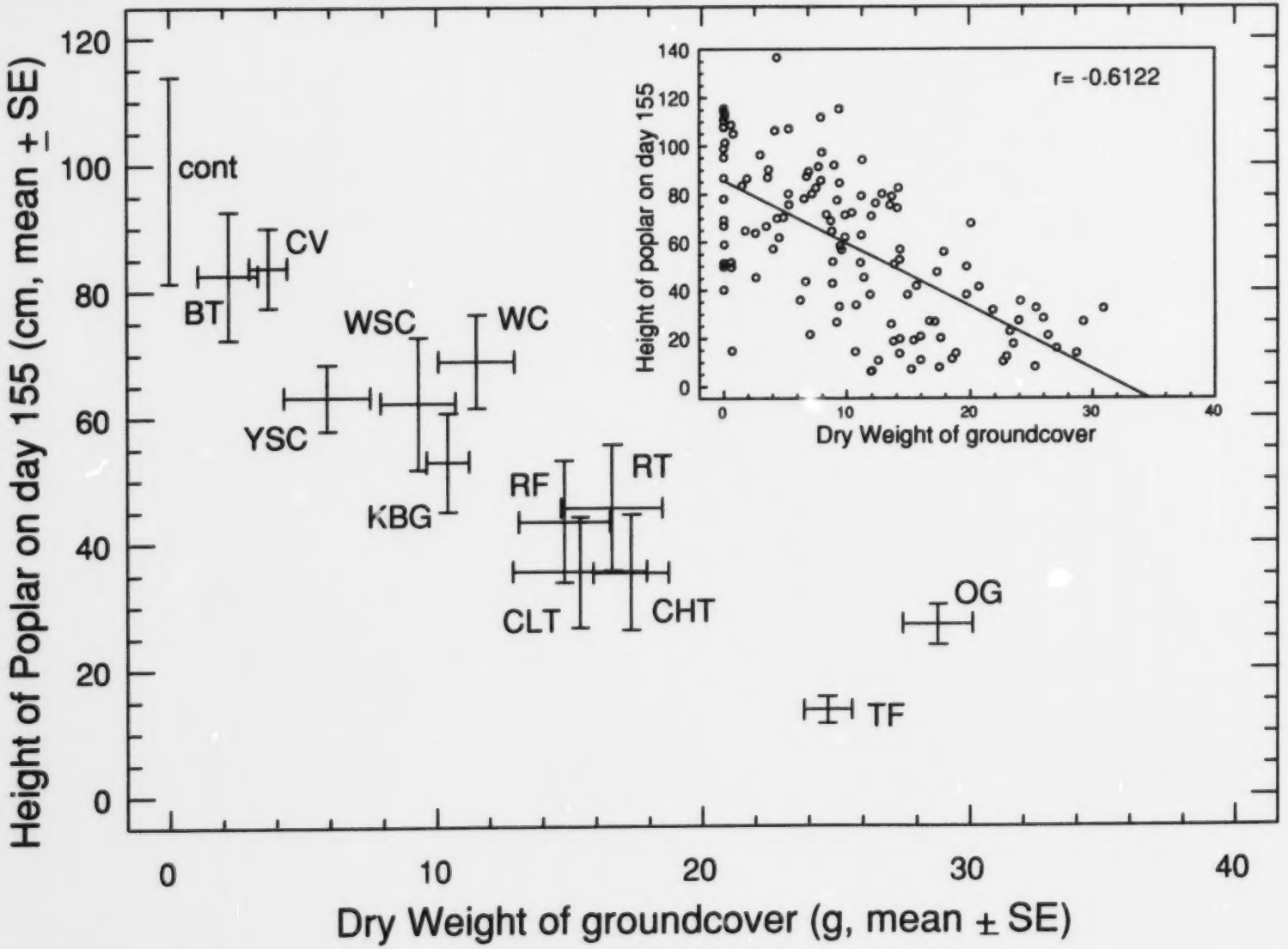
The results presented in Figure 2 suggest a large cover crop effect. However, most of the variation resulting from the treatment can be explained by the biomass of the crops and not the species *per se* (Figure 3). A ten-fold difference exits between the aboveground biomass of the cover crops, with the grasses having the larger weights. The relationship between poplar height and the dry weight of the cover crop is significant (r = -0.612264. p >0.00001), and a linear

Figure 2: The effect of 13 groundcovers on growth of poplar cuttings
(See table 1 for species codes.)



66-06

Figure 3: The relationship between poplar height and groundcover biomass



regression suggests that the groundcover biomass can account for 37.5% of the variation in poplar height. When this source of variation is removed from the analysis by including groundcover biomass as a covariate in the ANOVA, no significant treatment effects on poplar height, root weight, shoot weight or leaf chlorophyll could be contributed to the cover crop species (Table 3). However, the root:shoot ratio was not affected by cover crop biomass, and did show a groundcover effect significant at the $p = 0.09$ level (Table 3). When compared to the other groundcovers, the poplar sprouts in the orchard grass, tall fescue, champ timothy, Kentucky blue grass and birdsfoot trefoil treatments had proportionally more biomass in their shoot than in their roots.

Table 3

The results of the ANOVA showing the effects of 23 concurrently seeded groundcovers on the mean height, root biomass, shoot biomass, chlorophyll content and root:shoot ratio of the surviving poplar sprouts on day 155. The above ground biomass of the groundcover was used as a covariate.

Growth Measure	Covariate F	Covariate *p*	Groundcover F	Groundcover *p*
height	73.056	0.000	0.652	0.7929
root wt	19.242	0.000	0.662	0.7842
shoot wt	51.865	0.000	0.648	0.7970
chlorophyll	0.007	0.9360	0.982	0.4708
root:shoot	0.786	0.3866	1.640	0.0901

5.0 EXPERIMENT 3. SPRUCE AND MAPLE TRANSPLANTS

This experiment was designed to investigate the effects of different nutrient and moisture application rates on the interference ability of established groundcovers on tree transplants.

5.1 Methods

The groundcovers consisted of either white clover, climax timothy or bare ground, seeded at a density of 1 seed cm^{-2} (Table 1) 36 days prior to planting of the trees. The crops were fertilized weekly at 2 rates (0.060 g pot^{-1} and 0.125 g pot^{-1} of 20:20:20 NPK). The plants were watered 3 times weekly at a rate of either 150 or 300 ml pot^{-1}.

Dormant sugar maple (*Acer saccharum*) and white spruce seedlings (2 yr old) were obtained from the MNR nursery at Midhurst. These were planted into the established groundcovers. The initial height of each tree was measured. Ten trees of each species were harvested to determine initial dry weight (24 h at 80°C) of the root, shoot and foliage. Height, root collar diameter and dry weight of root, shoot and foliage were determined after 94 days of growth.

The experiment was analyzed as a 3 groundcover x 2 fertilizer x 2 water random factorial design with 5 replicates. The results of the maple and spruce experiments were analyzed separately.

5.2 Results

The groundcover had a large effect on the survival of the white spruce transplants. All 20 trees planted onto the bare ground treatment survived, whereas only 3 survived in the climax timothy cover (1 in the high fertilizer:low water, 2 in low fertilizer:high water treatments) and none survived in the white clover cover.

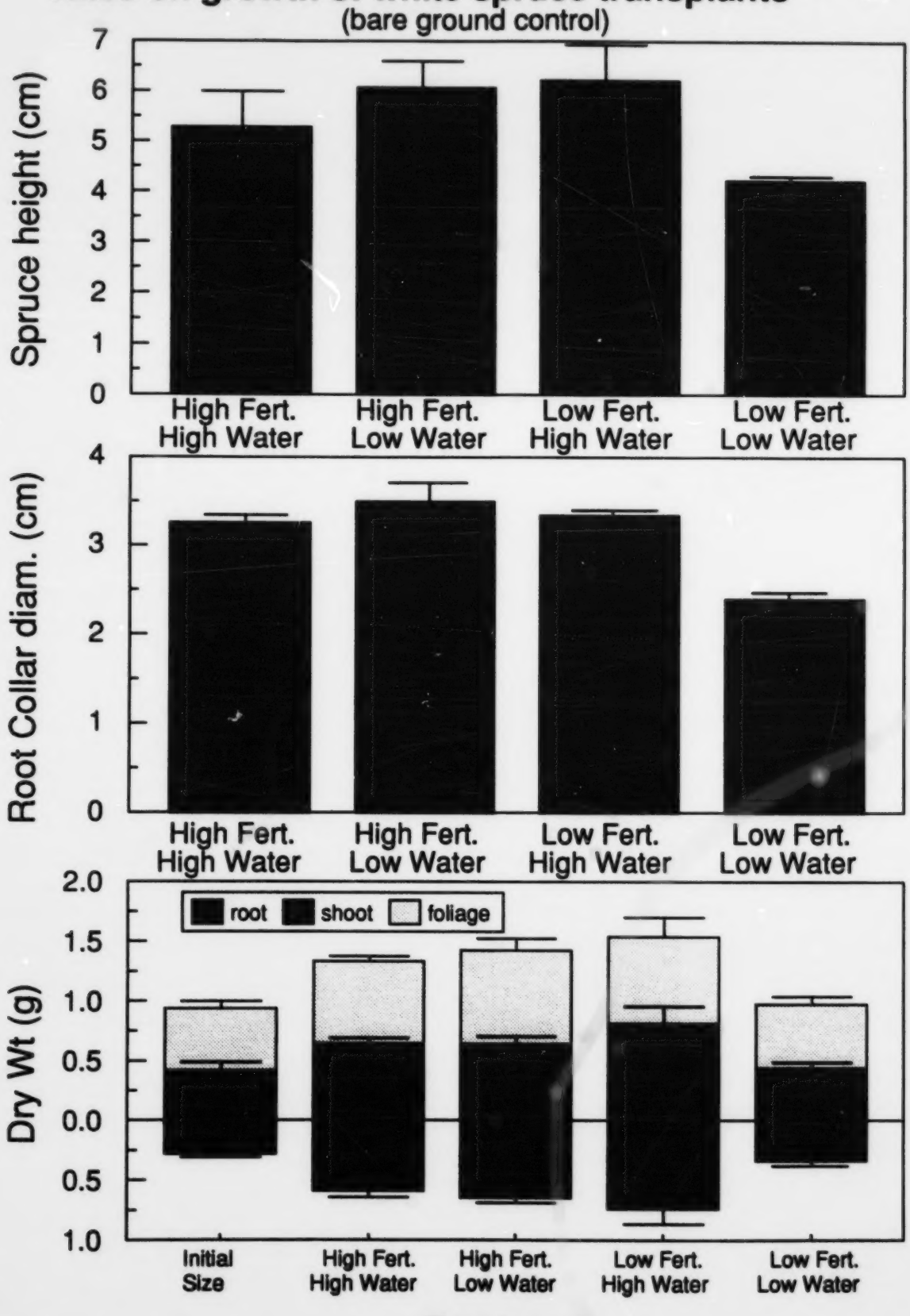
The effects of the factorial fertilizer and water treatments on the growth of the control spruce transplants is shown in Figure 4 and Table 4. The ANOVAs of the height, root collar diameter, root dry weight and shoot dry weight all indicate a significant interaction between fertilization and watering rates. In all cases, the low fertilizer:low water treatments produced the poorest growth. The watering rate had a significant main effect on root collar diameter, root dry weight and shoot dry weight, while fertilization was only significant as a main effect on the root collar diameter. No significant effects or interactions were observed for needle dry weight or root:shoot ratio.

Table 4

The results of the ANOVA showing the effects of a factorial combination of 2 fertilization and 2 watering rates on the height increment, root collar diameter(RCD), root biomass, shoot biomass, needle biomass, and root:shoot ratio of white spruce transplants growing in the bare ground control.

Growth Measure	Fertilizer F	*p*	Water F	*p*	Fert. x Water F	*p*
height	0.636	0.4453	1.168	0.2957	6.067	0.0255
RCD	10.281	0.0055	4.854	0.0428	13.759	0.0019
root wt	1.279	0.2748	6.050	0.0257	10.388	0.0053
shoot wt	0.057	0.8166	6.917	0.0182	6.770	0.0193
needle wt	1.286	0.2734	0.292	0.6019	2.297	0.1491
root:shoot	2.002	0.1762	0.066	0.8027	2.022	0.1742

Figure 4: Effect of 2 fertilization and watering rates on growth of white spruce transplants



The results of the ANOVAs on the sugar maple transplants are given in Table 5, and are summarized in Figure 5. Unlike the white spruce, all of the sugar maple transplants survived.

The type of groundcover had a significant effect on root collar diameter and root dry weight, and had a marginal effect on shoot dry weight (p = 0.0789). The highest root growth was observed in the controls, while the timothy and white clover treatments did not differ. In contrast, timothy exhibited the highest inhibition in shoot weight, while the white clover and control treatments had equivalent effects. The watering rate affected root collar diameter and had a marginal effect on shoot height (p = 0.10) and root dry weight (p = 0.0605). In all cases the lower watering rate produced the higher growth. The 2 fertilization rates did not differ in their effect on any growth measurement.

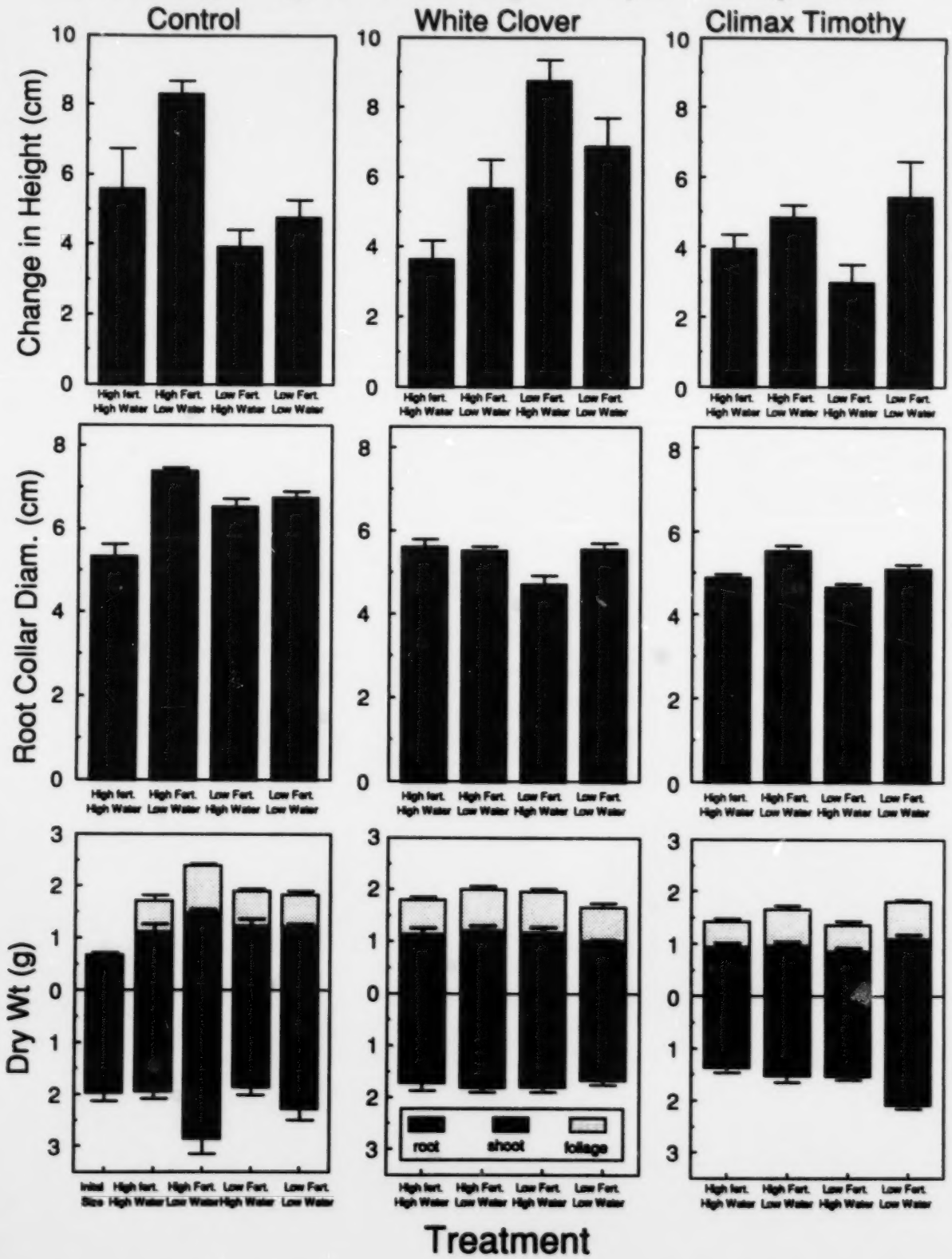
The significant and marginal effects of groundcover and watering rates on the root dry weight need to be interpreted with a large degree of caution. There was no significant difference between the root dry weight of the 10 sugar maple transplants sacrificed at the beginning of the experiment (1.96$\pm$0.30) and either the combined 60 maple samples (1.86$\pm$0.09, t = 0.4533, p = 0.6517) or the 20 bare ground controls (2.23$\pm$0.23, t = 0.6941, p = 0.4933) at the end of the experiment. This suggests that either the root system did not grow during the study or a considerable mass of root was not recovered during the harvesting.

Table 5

The results of the ANOVA showing the effects of a factorial combination of 3 groundcovers, 2 fertilization and 2 watering rates on the height increment, root collar diameter (RCD), root biomass, shoot biomass, foliage biomass and root:shoot ratio of the sugar maple transplants.

Growth Measure		Crop	Fert.	Water	Crop x F	Crop x W	F x W
height	F	1.168	0.517	2.808	1.149	0.951	1.559
	p	0.3193	0.4831	0.1000	0.3252	0.3933	0.2176
RCD F		7.102	0.223	4.104	0.423	0.516	0.358
	p	0.0020	0.6437	0.0482	0.6574	0.5999	0.5589
root wt.	F	4.441	0.001	3.690	1.334	1.300	0.099
	p	0.0168	0.9746	0.0605	0.2726	0.2817	0.7579
shoot wt.	F	2.674	0.151	0.675	0.108	0.380	0.422
	p	0.0789	0.7034	0.4239	0.8978	0.6861	0.5258
foliage wt.	F	1.302	0.273	2.642	0.295	0.835	2.458
	p	0.2811	0.6091	0.1104	0.7547	0.4400	0.1232
root:shoot	F	1.204	1.575	1.049	1.200	0.297	0.111
	p	0.3087	0.2153	0.3106	0.3097	0.7446	0.7445

Figure 5: The effect of groundcover, fertilizer and watering on growth of sugar maple transplants



6.0 DISCUSSION

There is an overall similarity in the interference potentials of the 2 groundcover groups tested in these experiments, such that the legumes could be generally classified as equivalent competitors, and all the grass species have generally the same effects. This is suggestive of a guild concept, where functional species groups can be defined based on similarities in the species life history traits, morphology and role in the community.

A guild is defined as a group of organisms which exploit the same resources in a similar manner (McNaughton and Wolf 1979). This concept was introduced in animal ecology as a grouping of species which used the same primary food source, but has not had much usage in plant ecology until recently. Boutin and Keddy (1989) suggest that this approach may be useful in reducing the complexity of community ecology studies. In the wetland system they were studying, 43 species could be reduced to 7 guilds.

The use of a guild approach in selection of cover crops is very appealing. The primary question for cover crop selection shifts from a complex "Which of the hundreds of crops species is the best inhibitor of the tens of potential tree invaders at this location?" to the simpler "Which of these few guilds (warm season grasses, tall forbs, raspberry-like shrubs) would be the best inhibitor of the major tree guild (conifer, pioneer hardwood, climax hardwood) at this location?" However, considerably more work is required before it can be determined if this degree of simplification is either justified or helpful. Bramble and Byrnes (1976) observed that life form alone cannot be used to predict which species may form a stable right-of-way community. Thus a large number of morphological and life history traits may be required to place a species into its appropriate guild (Boutin and Keddy (1989) used 27 traits). Measuring these traits may require experiments as time consuming as the experiments used in this report to measure a direct interference effect. But once a guild has been defined, the choice of the appropriate cover crop should be simpler.

Many individual plant traits, especially those relating to biomass or canopy spread, can be correlated to a species interference ability (Gaudet and Keddy 1988). Cover crop biomass has a large influence on the growth of the poplar cuttings (Figure 3). The similarities in interference potential amongst the legume and grass groups tested in this study may reflect a similarity in their biomass rather than their functional similarity as a guild.

The large difference in biomass which developed between the crop species in these experiments (Figure 3) presents some difficulty in interpreting the interference potentials of the various species tested. The size of an individual has a large effect on its interference potential. In many experiments, the winner is the individual with either the largest biomass or the fastest growth rates (Eissenstat and Caldwell 1987, Firbank and Watkinson 1987, Gaudet and Keddy 1988, Wilson 1988, Epp and Aarssen 1989, Keddy and Shipley 1989). However, it cannot be determined from this experiment whether the largest individual was the best competitor, or whether the best competitor was the species with the highest growth rate under the current experimental conditions. If the latter is true, then under a different set of experimental conditions a different species may be the best competitor.

In the poplar experiment, orchard grass and tall fescue had the highest biomass, while crown vetch and birdsfoot trefoil had the lowest (Figure 3). The vetch and trefoil are slow growing species, and a considerably different outcome may have resulted if these crops had been well established prior to the commencement of the experiment. Rice and Bazzaz (1989) suggest that comparisons should only be made between treatments with similar biomass, rather than density or chronological age, because the amount of actual growth is dependent upon the conditions under which the plants are grown and is thus an experimental, not a species, trait. Although the effects

of the biomass differences can be reduced by incorporating it in a covariance analysis (Table 3), it is preferable to design experiments such that the measurements are taken once a common biomass has been reached by each crop.

The differences in biomass between the cover crops were only measured in one experiment (Figure 3). However, it is important to keep this biomass difference in mind when reviewing the results of the other experiments.

An interesting pattern can be observed from the spruce seed experiment. There was a significant interaction between groundcover seeding date and spruce seed germination (Table 2). When the groundcovers were seeded 1 month prior to the spruce, the legumes had the larger inhibitory effects. In contrast, when the spruce and groundcovers were concurrently seeded the grasses had the higher interference effect on spruce seed germination (Figure 1a). However, by the end of this experiment, the inhibitory effects of the legumes had surpassed the grasses (Figure 1b, c). This difference was also observed in the other studies. There was higher mortality in the established white clover groundcover (100%) than the climax timothy groundcover (85%) in the spruce transplant study, while the grasses were the better inhibitors in the concurrently seeded poplar experiment (Figure 2). This suggests that grasses have an initial competitive advantage, probably due to their higher growth rates. However, in the long term, an established legume crop may have a higher interference potential.

It was surprising that the legumes were able to surpass the grasses in the concurrently seeded spruce experiments (Figure 1). It is generally considered that an early established individual, due to its larger size and ability to pre-empt resources, has the competitive advantage (Walters and Gilmore 1976, Eissenstat and Caldwell 1987, Firbank and Watkinson 1987, Wilson 1988, Keddy and Shipley 1989). The effects of early interference can affect tree growth for several years (Baskerville 1961, Balneaves 1982, Newton and Preest 1988). That the legumes were able to surpass the inhibitory advantage of the grasses in a relatively short experiment was unexpected. However, many of these arguments are based on a symmetrical competition model, where the effect of the target species on the competitor is potentially similar to the effect of the competitor on the target. For the spruce seeds, the interference is highly asymmetric. The growth rate of the spruce seedling is so slow that it would require several years for it to achieve a size sufficient for it to interfere with the cover crops. This slow growth rate permitted the legumes to catch up to the grasses and exhibit a large effect by the end of the experiment.

In contrast, the poplar cuttings have an extremely high growth potential, and were able to rapidly outgrow both the grasses and legume groundcovers. In this situation, the legumes were not able to exert the same effect by the end of the experiment. This also suggests that the interference effects are exhibited through a competition for light or aboveground space, and not nutrients, water or rooting space.

Competition for space or light is also suggested by the nutrient and moisture manipulations used in the maple transplant experiment. No interactions were observed between the groundcover and the watering or fertilization treatments (Table 5). However, a large degree of caution is necessary to interpret these results, as competition between groundcovers and trees for moisture or water has been implicated in several studies (see Brown (1989a) for a summary). Growth of the sugar maple controls was inhibited at the higher watering rate (Figure 5, Table 5), so the presence of a groundcover which utilizes water may actually alleviate this inhibition. The fertilizer rates used did not induce a difference in maple growth in the controls or the 2 groundcovers, suggesting that either the lowest rate used (0.060 g fertilizer per 15 cm pot) was adequate for maximum growth of the maple transplants, or the maple had sufficient nutrient reserves to compensate for the low nutrient availability.

The fertilization rates used in this experiment, which corresponds to approximately 100 and 200 kg N $ha^{-1}yr^{-1}$, are similar to those used in the field for ecosystem manipulation studies (Harcombe 1977, Tilman 1987, West 1987, Carson and Barrett 1988). They are also within the range used by the orchard and forestry industries for site improvement (Bould and Jarrett 1962, Clark and McLean 1979, Atkinson and Lipecki 1980, McLaughlin *et al* 1985, Mroz *et al* 1985, Margolis and Waring 1986, Munson and Timmer 1989, Jokela *et al* 1989) and are below the level required for optimum growth for many containerized trees (Swan 1960, Van Den Driessche 1982, Maronek *et al* 1982, Ekwebelam and Reid 1983, Lieffers and Titus 1989, Munson and Timmer 1989). West (1987) suggests that a minimum application of 200 kg N ha^{-1} was necessary to improve upon the interference abilities of rights-of-way vegetation. However, this fertilization rate supplied nitrogen at a level 2 to 3 orders of magnitude above that observed in rights-of-way soils near Barrie (0.675 to 6.21 kg N ha^{-1}, Brown 1988), and 1 to 2 orders above the natural rates of nitrate supply (Montagnini *et al* 1989, F.S. Spencer (personal comm.)).

The different fertilization and water rates will also affect cover crop biomass, which will in turn alter the degree of interference. Crop biomass was not measured in this experiment, thus it is difficult to interpret the results.

The spruce, maple and poplar are being used in this study as a phytometer, the use of a common indicator species to rank the interference potentials of the different cover crop species. This approach was championed by Gaudet and Keddy (1988) as a more realistic way of investigating community interactions than the usual approach of deriving competitive hierarchies from a matrix of several multiple species competition experiments. Although this approach has received some criticisms (Bailey 1989, Firbank and Watkinson 1989, Silvertown 1989), it could be useful in the selection of appropriate cover crop species.

One might question the development of a maintenance program which relies on the results obtained from only one phytometer. The outcome of a competitive interaction should be easier to predict as the species involved become less similar (Keddy and Shipley 1989). In this context, the differences between the groundcovers (fern, forb, grasses, or small shrubs) and the target trees are so large that a guild approach may be justified. However, the opposite rankings which were obtained by the spruce seed and poplar cutting experiments (Figure 1, 2) suggest that several different tree phytometers should be used to verify the results.

7.0 CONCLUSIONS

1. The different groundcovers affected germination, survival, root collar diameter, root dry weight and shoot dry weight of the tree transplants and seeds. The only tree in which height growth was affected by the groundcover was Carolina poplar.

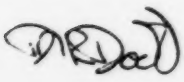
2. An established groundcover has a larger interference effect.

3. The biomass of the groundcovers represented a major component of their interference abilities.

4. The watering rate affected growth of the white spruce and sugar maple transplants but did not interact with the groundcover effects.

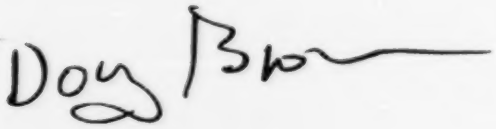
5. Studies using more realistic fertilization rates are necessary to investigate the role of this parameter.

Approved by:



D.J.R. Dodd
Manager
Chemical Research Dept

Prepared by:



D. Brown
Biologist
Biological Research Section

Reviewed by:

O.T. Melo
Acting Section Head
Biological Research Section

REFERENCES

Atkinson, D. and J. Lipecki. 1980. The influence of orchard soil management on the growth and productivity of young apple trees. Fruit Science Reports 7, 49-54.

Bailey, R.C. 1989. Nature 337, 122.

Balneaves, J.M. 1982. Grass control for radiata pine establishment on droughty sites. New Zealand Journal of Forestry 27, 259-276.

Baskerville, G. L. 1961. Response of young fir and spruce to release from shrub competition. Canadian Department of Forestry, Forest Research Division, Technical Note No. 98. 14pp.

Bould, C. and R.M. Jarrett. 1962. The effect of cover crops and NPK fertilizers on growth, crop yield and leaf nutrient status of young dessert apple trees. Journal of Horticultural Science 37, 58-82.

Boutin, C. and P.A. Keddy. 1989. Using the guild concept as a tool to study wetland communities. Bulletin of the Ecological Society of America, Supplement 70, 67.

Bramble, W. C. and W. R. Byrnes. 1976. Development of a stable, low plant cover on a utility right-of-way. *In* Proceedings of the first international symposium on environmental concerns in right-of-way management. Edited by R. Tillman. Mississippi State University Press, pp. 168-176.

Brown, D. 1988. The relationship between vegetation, soil texture, nutrient status and herbicide treatments on transmission rights-of-way in the vicinity of Essa TS, Georgian Bay Region. Ontario Hydro Research Division Report 88-211-K. Toronto. 35pp.

Brown, D. 1989a. The use of cover crops for the maintenance of rights-of-way vegetation: a survey of the literature on succession, cover crops, competition and trees. Ontario Hydro Research Division Report 89-275-K. Toronto. 41pp.

Brown, D. 1989b. The stability of six different rights-of-way plant communities in the vicinity of Essa TS and their interference potential on *Fraxinus pennsylvanica* transplants. Ontario Hydro Research Division, Report 89-88-K. Toronto. 22pp.

Brown, D. 1990. The use of cover crops to control tree invasion on a right-of-way near Tobermory. II. Crop establishment and tree invasion in the first growing season. Ontario Hydro Research Division Report 89-316-K. Toronto. 20pp.

Carson, W.P. and G.W. Barrett. 1988. Succession in old-field plant communities: effects of contrasting types of nutrient enrichment. Ecology 64, 984-994.

Clark, M.B. and A. McLean. 1979. Growth of lodgepole pine seedlings in competition with grass. Research Branch, British Columbia Ministry of Forests, Research Note #86. Victoria, B.C. 11pp.

Eissenstat, D.M. and M.M. Caldwell. 1987. Characteristics of successful competitors: an evaluation of potential growth rate in two cold desert tussock grasses. Oecologia 71, 167-173.

Ekwebelam, S.A. and C.P.P. Reid. 1983. Effect of light, nitrogen fertilization, and mycorrhizal fungi on growth and photosynthesis of lodgepole pine seedlings. Canadian Journal of Forest Research **13**, 1099-1106.

Epp, G.A. and L.W. Aarssen. 1989. Predicting vegetation patterns from attributes of plant growth in grassland species. Canadian Journal of Botany **67**, 2953-2959.

Firbank, L.G. and A.R. Watkinson. 1987. On the analysis of competition at the level of the individual plant. Oecologia **71**, 308-317.

Firbank, L.G. and A.R. Watkinson. 1989. Nature **337**, 122.

Gaudet, C.L. and P.A. Keddy. 1988. A comparative approach to predicting competitive ability from plant traits. Nature **334**, 242-243.

Harcombe, P.A. 1977. The influence of fertilization on some aspects of succession. *Ecology* **58**, 1375-1383.

Jokela, E.J., R.B. Harding and C.A. Nowak. 1989. Long-term effects of fertilization on stem form, growth relations, and yield of slash pine. Forest Science **35**, 832-842.

Keddy, P.A. and B. Shipley. 1989. Competitive hierarchies in herbaceous plant communities. Oikos **54**, 234-241.

Lieffers, V.J. and S.J. Titus. 1989. The effects of stem density and nutrient status on size inequality and resource allocation in lodgepole pine and white spruce seedlings. Canadian Journal of Botany **67**, 2900-2903.

Margolis, H.A. and R.H. Waring. 1986. Carbon and nitrogen allocation patterns of Douglas-fir seedlings fertilized with nitrogen in autumn. I. Overwintering metabolism. Canadian Journal of Forest Research **16**, 897-902.

Maronek, D.M., J.W. Hendrix and P.L. Cornelius. 1982. Slow-release fertilizers optimize mycorrhizal development on container-grown pine seedlings inoculated with *Pisolithus tinctorius*. Journal of the American Society for Horticultural Science **107**, 1104-1110.

McLaughlin, R.A., P.E. Pope and E.A. Hansen. 1985. Nitrogen fertilization and ground cover in a hybrid poplar plantation: effects on nitrate leaching. Journal of Environmental Quality **14**, 241-245.

McNaughton, S. J. and L. L. Wolf. 1979. General Ecology. 2nd ed. Holt, Rinehart and Winston, New York.

Montagnini, F., B.L. Haines, W.T. Swank and J.B. Waide. 1989. Nitrification in undisturbed mixed hardwoods and manipulated forests in the southern Appalachian mountains of North Carolina. Canadian Journal of Forest Research **19**, 1226-1234.

Mroz, G.D., D.J. Frederick and M.F. Jurgensen. 1985. Site and fertilizer effects on northern hardwood stump sprouting. Canadian Journal of Forest Research **15**, 535-543.

Munson, A.D. and V.R. Timmer. 1989. Site-specific growth and nutrition of planted *Picea mariana* in the Ontario clay belt. II. Effects of nitrogen fertilization. Canadian Journal of Forest Research **19**, 171-178.

Newton, M. and D.S. Preest. 1988. Growth and water relations of Douglas fir (*Pseudotsuga menziesii*) seedlings under different weed control regimes. Weed Science **36**, 653-662.

Ontario Hydro. 1983. A guide to seeding rights-of-way cover crops. Department of Transmission Environment HG&T. 17p.

Rice, S.A. and F.A. Bazzaz. 1989. Quantification of plasticity of plant traits in response to light intensity: comparing phenotypes at a common weight. Oecologia **78**, 502-507.

Silvertown, J. 1989. Nature **337**, 123.

Suffling, R. 1979. Environmental aspects of cover crops on Ontario Hydro rights-of-way. University of Waterloo, Research Institute Project 707-11. Waterloo. 207pp.

Swan, H.S.D. 1960. The mineral nutrition of Canadian pulpwood species. I. The influence of nitrogen, phosphorus, potassium and magnesium deficiencies on the growth and development of white spruce, black spruce, jack pine and western hemlock seedlings grown in a controlled environment. Pulp and Paper Research Institute of Canada, Technical Report No. 168. Montreal. 66pp.

Tilman, D. 1987. Secondary succession and the pattern of plant dominance along experimental nitrogen gradients. Ecological Monographs **57**, 189-214.

Van Den Driessche, R. 1982. Relationship between spacing and nitrogen fertilization of seedlings in the nursery, seedling size, and outplanting performance. Canadian Journal of Forest Research **12**, 865-875.

Walters, D.T. and A.R. Gilmore. 1976. Allelopathic effects of fescue on the growth of sweetgum. Journal of Chemical Ecology **2**, 469-479.

West, S. D. 1987. Nitrogen fertilization and the suppression of tree establishment on western Washington rights-of-way. *In Proceedings*. Fourth symposium on environmental concerns in rights-of-way management. Edited by W.R. Byrnes and H.A. Holt. Department of Forestry and Natural Resources, Perdue University, pp. 128-131.

Wilson, J.B. 1988. The effect of initial advantage on the course of plant competition. *Oikos* **51**, 19-24.